

Concentration quenching of Eu related luminescence in Eu-doped GaN studied by EXAFS analysis

Shinichi MORISHIMA, Hyungjin BANG, Yoshinori HAGIO, Takahiro MARUYAMA²,

Katsuhiro AKIMOTO and Masaharu NOMURA¹

Institute of Applied Physics, University of Tsukuba, 1-1-1 Ten-nodai, Tsukuba, Ibaraki, 305-8573, Japan,

Tel: +81-298-53-6177, Fax: +81-298-55-7440, E-mail: morisima@esys.tsukuba.ac.jp

¹*Photon Factory, Institute of Materials Structure Science, High Energy Accelerator Research Organization, Oho, Tsukuba, Ibaraki, 305-0801, Japan*

²*Present address: Department of Photonics, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga 525-8577, Japan*

Local structures around Eu atoms in Eu-doped GaN have been investigated by fluorescence extended X-ray absorption fine structure (EXAFS) analysis in order to study the cause of concentration quenching of luminescence from Eu ion in Eu-doped GaN, and the concentration quenching was found to be caused by mainly a formation of EuN compound.

Rare-earth(RE) doped GaN can be regarded as great potential materials in application for optical devices since they show sharp and intense luminescence which is not so affected by chemical environment. There are several reports regarding emissions from various RE (Er, Dy, Tm, Sm, Ho, Pr, Tb and Eu) ion in GaN,¹⁻⁴⁾ in particular, green to red emission seems to be interesting that because of the difficulty of InGaN growth with high content of In.

We have shown that single crystalline Eu-doped GaN was successfully grown on sapphire (0001) substrates, and that a red-emission from Eu-doped GaN was observed at 622nm originating from intra 4f-4f transition of Eu³⁺ ion. Furthermore, the peak position and intensity of the red-emission was found to exhibit weak temperature dependence.^{5, 6)} The red-emission is generated through an excitation of GaN and the external emission efficiency was estimated to be about 0.2 at room temperature in case of the Eu concentration of about 2%. The efficiency abruptly decreased for the Eu concentration more than 2%.⁷⁾ The cause of the luminescence quenching is not well understood yet.

The Eu-doped GaN was grown on sapphire(0001) substrates by gas-source MEB using metallic Ga(6N) , Eu(3N) and uncracked NH₃(6N) gas. Eu concentration in GaN was estimated to be about 0.1%, 2.2%, and 16.6% for samples (a), (b), and (c), respectively, by Rutherford back scattering spectrometry. The photoluminescence (PL) measurement at 77K was carried out using He-Cd laser (325nm) as an excitation source. The EXAFS measurements were carried out on beamline(BL)-12C at Photon Factory in High Acceleration Research Organization. The Eu *L*_{III}-edge EXAFS spectra were obtained in fluorescence-detection mode at room temperature.

Fig. 1. shows PL spectra for samples (a), (b) and (c) of Eu-doped GaN. In sample (a), near band-edge emission were observed together with red-emission at 622 nm which can be assigned as ⁵D₀-⁷F₂ transition of Eu³⁺. The emission intensity is roughly proportional to the concentration of Eu³⁺ up to about 2%, and then the intensity abruptly decreased.

Fig. 2. shows Fourier transform of the *k*³-weighed EXAFS spectra for Eu-doped GaN for various Eu concentrations. In upper two spectra, the peaks at about 1.8 and the dominant peaks at about 3.0

correspond to a contribution from the first and second nearest neighbor atoms, respectively, and both spectra are quite similar each other. The analytical results show that the nearest neighbor atoms are nitrogen and makes four coordination. Therefore, it is reasonably considered that the Eu atom is incorporated into Ga lattice site. On the other hand, the spectrum (c) has complicated structure compared with the spectra (a) and (b). From the analysis in the region indicated as “ α ” and “ β ” in the spectrum (c), two kinds of bond length between Eu and N, and existence of Eu in addition to Ga, respectively, were suggested. These results indicate a formation and segregation of EuN compound. As mentioned above, the red-emission is generated through an excitation of GaN, therefore, it may not be possible to generate a red-emission in EuN since the energy transfer from GaN to EuN is difficult. Concentration quenching of Eu luminescence in Eu highly doped GaN may be caused by the formation of EuN compound.

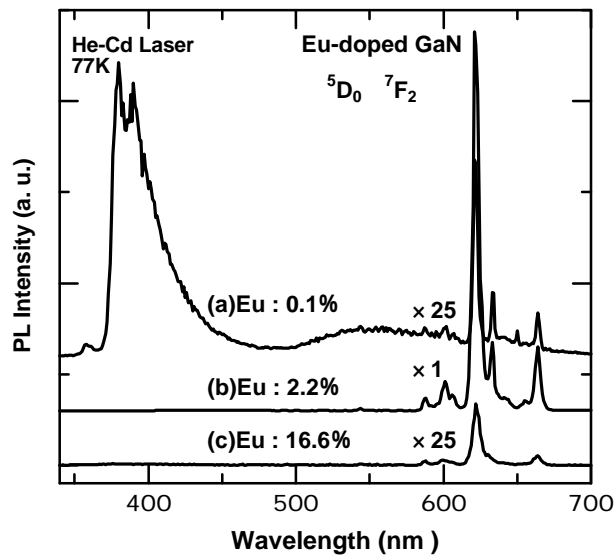


Fig. 1. Photoluminescence spectra measured at 77K from Eu-doped GaN with the Eu content of (a) 0.1%, (b) 2.2% and (c) 16.6%.

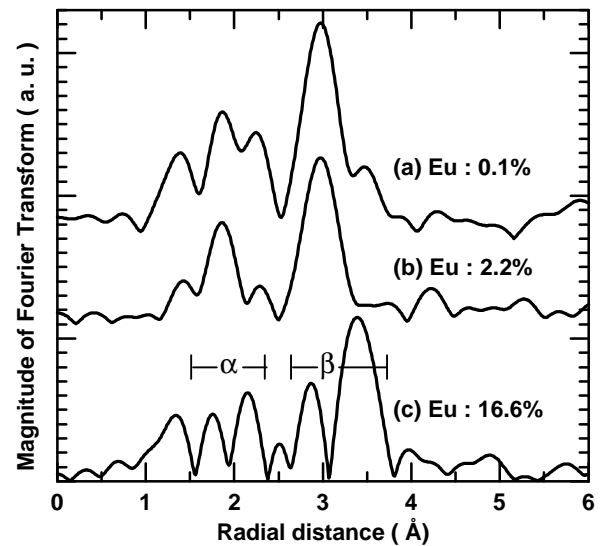


Fig. 2. Fourier transform of the k^3 -weighted Eu L_{III} -edge EXAFS spectra for Eu-doped GaN with the Eu content of (a) 0.1%, (b) 2.2% and (c) 16.6%.

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